

## BEACON TO VISUALLY LOCATE MEMORY MODULE

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### 5                    BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention relates generally to computer systems.  
10    More particularly, the present invention relates to memory systems.

#### Description of the Background Art

In today's computer industry, dynamic random access memories  
15    (DRAMs) are one of the dominant memory technologies. DRAMs are the preferred choice for large main memories because they are inexpensive, fast and consume little power. DRAMs are typically manufactured in discrete semiconductor packages having different input/output (I/O) data widths of, for example, sixteen, thirty-two, or sixty-four, or more data bits.

20                    The number of data bits that a computer can simultaneously address and manipulate, i.e., the computer bus width, is typically much larger than that commonly available with DRAMs. To accommodate these bus widths, groups of DRAMs are typically packaged together to form memory modules, such as, for example, DIMMs (Dual In-line Memory Modules) and other types of  
25    memory modules.

FIG. 1A shows a side view of a conventional memory system **100** with two DIMM modules. The memory system **100** includes a CPU or memory controller **102** affixed to a motherboard **106** and two dual in line memory modules **108a** and **108b**. The two memory modules **108a-b** shown each  
30    includes N memory devices **112** connected in parallel. Assuming for purposes of discussion that N is equal to eighteen, the eighteen memory devices **112a-N** on each memory module **108a** and **108b** are connected to the memory controller

**102** by a data bus **114**, which includes board trace portions **116**, a connectors **118** and a module trace portions **120**.

FIG. 1B shows a block diagram of the memory structure of the memory modules of the memory system **100** shown in FIG. 1A. In FIG. 1B, the data bus is 72 bits wide where 64 bits are used for data and 8 bits are used for error correction. Each of the eighteen memory devices on the memory module **108a-b** is 4 bits. The eighteen memory devices are connected in parallel so that for each memory operation, the output onto the data bus **114** is 72 bits wide.

FIG. 1C shows a clock pulse for reading or writing to a memory location of the memory system **100** shown in FIG. 1A. The memory controller **102** reads a single word or memory location from a single memory module at a time. Assuming a single data rate (SDR) system and a read operation, the memory location in memory module **108** having the address 000000 is read at the clock edge  $t_1$ . The contents of the memory location is 72 bits wide. No memory operation occurs at clock edge  $t_2$ . A second memory location having the address location 000001 in memory module **108** is read at the clock edge  $t_3$ .

FIG. 2A shows a side view of a conventional memory system **200** having eight DIMM modules. Similar to the configuration shown in FIG. 1A, the memory system **200** shown in FIG. 2A includes a CPU or memory controller **202** affixed to a motherboard **206**. However, this configuration includes eight dual in line memory modules **208a-h** instead of the two DIMMs **108a-b** shown in FIG. 1A. The eight memory modules **208a-h** shown each includes N memory devices **212**. The memory controller **202** is connected to the eight memory modules **208a-h** by a data bus **214**, which includes board trace portions **216**, connectors **218** and module trace portions **220**.

FIG. 2B shows a block diagram of the memory structure of the memory system **200** shown in FIG. 2A. In the system shown, the data bus is 144 bits wide where 128 bits are used for data and 16 bits are used for error correction. Preferably each memory module includes eighteen memory devices (N=18), each memory device being 4 bits wide. For each memory module, the memory devices are connected in parallel. Data is read from two memory modules simultaneously, so that for each memory operation, the output onto the data bus **214** is 144 bits wide.

FIG. 2C shows a clock pulse for reading or writing to a memory location of the memory system **200** shown in FIG. 2A. The memory controller **202** reads a single word or memory location from a single memory module at a time. Assuming a double data rate (DDR) system and a memory read operation, the memory location in memory module **208a** having the address 000000 and the memory location in memory module **208e** having the address 000000 are both read simultaneously at the clock edge  $t_1$ . A second memory location in memory module **208a** having the address location 000001 and a second memory location having the address 000001 in memory module **208e** are both read simultaneously at the clock edge  $t_2$ .

The above-discussed relatively simple memory systems are merely illustrative examples discussed for background purposes. There are numerous other memory system configurations, some much larger and more complex than those discussed above. With the ubiquity of memory systems in computer systems, improvements in the methods and apparatus for utilizing and maintaining such memory systems are highly desirable.

### SUMMARY

One embodiment of the invention pertains to a method of visually locating a memory module. An electronic communication is received by circuitry on the memory module to be visually located. A beacon state in the memory module is activated due to receipt of the electronic communication. A beacon device on the memory module is electronically turned on when the beacon state is activated to draw attention to that memory module.

Another embodiment of the invention pertains to an apparatus to visually locate a memory module in a memory system with a plurality of memory modules. The apparatus includes a system board, a plurality of memory modules, and a beacon unit on a memory module. The system board includes a memory controller and a plurality of memory module slots on the system board. The plurality of memory modules are seated in the slots. The beacon unit includes a beacon device and control circuitry for turning on the beacon device

when an electronic communication to turn on the beacon device is received by that memory module.

### BRIEF DESCRIPTION OF THE DRAWINGS

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FIG. 1A shows a side view of a conventional memory system having two DIMM modules.

FIG. 1B shows a block diagram of the memory structure of the memory modules of the memory system shown in FIG. 1A.

FIG. 1C shows a clock pulse for reading or writing to a memory location of the memory system shown in FIG. 1A.

FIG. 2A shows a side view of a conventional memory system having eight DIMM modules.

FIG. 2B shows a block diagram of the memory structure of the memory system shown in FIG. 2A.

FIG. 2C shows a clock pulse for reading or writing to a memory location of the memory system shown in FIG. 2A.

FIG. 3 is a flow chart of a conventional method of locating a faulty memory module.

FIG. 4 is a schematic diagram of a system for drawing attention to a faulty memory module in accordance with an embodiment of the invention.

FIG. 5 is a flow chart of a method of locating a faulty memory module in accordance with an embodiment of the invention.

FIGS. 6A, 6B, and 6C depict an example electromechanical beacon device in accordance with an embodiment of the invention.

### DETAILED DESCRIPTION

Most computer memory systems are made up of DRAMs that typically reside on individual DIMMs. Each DIMM is made up of a "set" of DRAMs, typically 32 to 36 in number, that plug into slots on a motherboard. A computer memory system may include anywhere from a few DIMMs (for example, in a personal computer or a small server) to thousands of DIMMs (for

example, in a large server system). High end servers also typically include high availability features such as memory chip redundancy and hot swapping.

When a permanent memory error occurs (for example, a stuck-at bit, a stuck-open bit, or a "weak cell"), the location of the error is typically kept in system logs. The system logs reside in a central location such as a disk drive of the system, or on the system board. The system log typically tracks the logical DIMM number and DRAM location that has the error.

While identifying a particular memory module by its logical DIMM number is sufficient and useful for the operating system or other software, such identification is not directly useful for a repair technician or other person wishing to remove a faulty DIMM. Such identification for removal is especially useful for systems with hot-pluggable DIMMs. In order for a person to locate the DIMM corresponding to a memory error, the person must translate the logical DIMM number to a visually-identifiable slot location.

Previous ways to accomplish this translation include the following cumbersome techniques. First, a manual for the computer system may be reviewed to determine the mapping between the visually-identifiable locations and the logical numbers. This technique is disadvantageously time consuming and prone to human error. Furthermore, finding the manual may be difficult in remote areas or easily forgotten by a repair person.

Second, instead of consulting a manual, a web page or other external program may be used to map a logical DIMM number to a visually-identifiable location on the motherboard. This technique is also disadvantageously time consuming. In addition, this technique requires the creation and maintenance of the web page or external program. Furthermore, access to the web page or external program must be provided to a repair person in remote locations.

Third, a chassis may be labeled to visually correlate its DIMM slots to the logical DIMM numbers. This technique requires an extra step of labeling each of the DIMM slots with its corresponding logical DIMM number. Such labeling is tedious and may not be done accurately. Furthermore, this technique requires space on the chassis to attach the label, and such space may be limited, especially in compact systems.

Fourth, a diagnostics board may be used. The diagnostics board typically codes multiple failures within a few light emitting diodes (LEDs). A repair person or user should be trained to use the diagnostics board. Such a diagnostics board is usually used in combination with one of the above three  
5 methods, since using the diagnostics board alone is typically confusing to the user.

An embodiment of the present invention provides circuitry to electronically translate the logical DIMM number into a visually-identifiable DIMM location. In accordance with one embodiment, the DIMM location may be made  
10 visually-identifiable by electronically turning on or activating a light emitting device (LED) on the DIMM needing to be found. In another embodiment, the DIMM location may be made visually-identifiable by electronically turning on or activating an electromechanical flag type device. Advantageously, such the electromechanical device remains activated even in the absence of power to the  
15 device. The LED, electromechanical flag, or other beacon device that is turned on or activated serves as a "beacon" to rapidly draw the attention of a repair person or other user to that particular DIMM. This technique is advantageous over prior techniques because it simplifies DIMM identification and lowers the need for diagrams and documentation.

In one embodiment, the beacon device may comprise a fault indicator. The fault indicator beacon on a DIMM may be electronically turned on or activated under the control of system firmware to indicate that the DIMM includes a problematic memory fault. In another embodiment, the beacon device may comprise a locator. The locator beacon may be set by a user to provide a  
20 beacon to draw attention to a particular DIMM, whether or not that DIMM includes a memory fault. In another embodiment, each DIMM may include both a fault indicator beacon and a locator beacon. The two beacons may be, for instance, of different colors to clearly distinguish them. Instead of or in addition to the above, an embodiment of the invention may include circuitry on the DIMM  
25 such that the DIMM itself may self-diagnose problems and turn its fault indicator beacon on to draw attention of a repair person or user.  
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FIG. 3 is a flow chart of a conventional method of locating a faulty memory module. Sometime during the operation of the computer system, a

memory error is detected **302**. The specific location of the memory error is determined **304**. The memory error detection **302** and location determination **304** may be performed, for example, by the manageability processor. The specific location may be indicated as being at specific address(es) of specific  
5 DRAM(s) on a particular memory module. To track the memory error, the memory error information is stored **306** in a system log. The system log may be kept, for example, on the system board or on a system disk.

If a memory module with memory errors thereon is to be removed  
**310** for purposes of replacement or repair, then the memory module to be  
10 removed must first be visually located **308** by the repair technician or other user. As discussed above, there are conventional techniques to visually locate the memory module including: using a manual **308a**; using a web page or an external program **308b**; and using labels on the chassis **308c**. Referring to a manual **308a** is disadvantageously time consuming and prone to human error.  
15 Furthermore, finding the manual may be difficult in remote areas or easily forgotten by a repair person. Using a web page or an external program **308b** technique is also disadvantageously time consuming. In addition, this technique requires the creation and maintenance of the web page or external program. Furthermore, access to the web page or external program must be provided to a  
20 repair person in remote locations. Using labels on the chassis **308c** requires an extra step of labeling each of the DIMM slots with its corresponding logical DIMM number. Moreover, the labeling is tedious, may not be done accurately, and requires sufficient space on the chassis to attach the label.

FIG. 4 is a schematic diagram of a system for drawing attention to  
25 a faulty memory module in accordance with an embodiment of the invention. The system includes a system board **400** and multiple DIMM modules **450**. In some larger computing systems, the system board **400** may be referred to as a cell board **400**.

The system board **400** includes various components. A central  
30 processor unit (CPU) **402** executes software instructions and operates as a "brain" that coordinates the operation of other components on the board **400**. Although one CPU **402** is illustrated, an actual system may utilize a single CPU or multiple CPUs **402** for this functionality. The CPU **402** is shown as

communicatively coupled to a memory controller **404** and a processor dependent hardware (PDH) interface **408**. These communicative couplings may comprise, for example, a communications bus or other communications means. Other components (not illustrated) may also, of course, be communicatively coupled to the CPU **402**, such as an input/output interface, a data storage interface, a display interface, and other devices.

The memory controller **404** is used to control the reading of data from and writing of data to the DRAM chips on the DIMM modules **450**. The memory controller **404** may be implemented to operate, for example, similarly to the memory controllers discussed above in relation to FIGS. 1 and 2. The specific operation of the memory controller **404** will depend upon the specific characteristics of the memory being controlled (for example, whether the DRAM is asynchronous or synchronous, whether the DRAM is single data rate or double data rate, whether it is direct Rambus® DRAM (DRDRAM®), and so on). Embodiments of the present invention should not typically be limited to a particular type of DRAM.

In one embodiment, a manageability processor (MP) **420** may be included on the system board **400**. The MP **420** may be used to control the monitoring of status, the logging of events and abnormal conditions, and the recovery capabilities in relation to the memory system. In one embodiment, the manageability processor **420** may be configured to be compliant with the intelligent platform management interface (IPMI) specification. The IPMI specification is currently available from Intel via the Internet by way of the following URL: <http://www.intel.com/design/servers/ipmi/spec.htm>. The Intelligent Management Platform provides functions that are available independent of the main processors, BIOS, and operating system. IPMI messaging uses a request/response protocol. IPMI request messages (also called commands) are grouped into functional command sets, using a field called the network function code. There are command sets for sensor and event related commands, chassis commands, and so on.

The PDH interface **408** allows the CPU **402** and/or the MP **420** to communicate with other components shown, including a processor dependent code (PDC) unit **410**, scratch memory **412**, and a memory error interface unit



**406.** In the embodiment illustrated in FIG. 4, the system board **400** includes both the CPU **402** and the MP **420** and both are communicatively coupled to the PDH interface **408**. In another embodiment, the system board **400** includes both the CPU **402** and the MP **420**, but only the MP **420** is communicatively coupled to the PDH interface **408**. In another embodiment, the system board **400** includes only the CPU **402** and not the MP **420**.

The PDH interface **408** may be implemented using a microcontroller. The PDC unit **410** may comprise a form of non-volatile memory, such as, for instance, flash memory or a type of read only memory (ROM). The PDC unit **410** may be configured to include boot code and error handling code that may be executed by the CPU **402** and/or the manageability processor **420**. The scratch memory **412** may be implemented using volatile and/or non-volatile scratch RAM. The scratch memory **412** is utilized to temporarily store data.

The memory error interface **406** is communicatively coupled to the beacon units **454** on the DIMM modules **450**. In one embodiment, the communicative coupling may be implemented using an IPMI bus. In another embodiment, the communicative coupling may be implemented using an I2C (Inter-IC) bus. Each beacon unit **454** may comprise one or more beacon devices and related control circuitry. The beacon devices may comprise LEDs, electromechanical flags, or other devices. In one embodiment, the beacon unit **454** may include a fault indicator beacon. In another embodiment, the beacon unit **454** may include a locator beacon. In another embodiment, the beacon unit **454** may include both a fault indicator beacon and a locator beacon. Other beacon types may also be included in other embodiments. If multiple beacon devices are included on a DIMM, different colors for the beacon devices may be used to more clearly distinguish them. For example, different color LEDs or different color electromechanical flags may be used. The beacon devices may be turned on or off by setting or resetting associated control registers in the beacon units **454**.

The fault indicator beacon may be electronically turned on by system firmware to indicate that the DIMM includes a problematic memory fault. The locator beacon may be set by software on the computer system to provide a beacon to draw a user's attention to a particular DIMM, whether or not that

DIMM includes a memory fault. Instead or in addition to the system firmware turning the beacon device(s) on, an embodiment of the invention may include circuitry on the DIMM such that the DIMM itself may self-diagnose problems and turn on its fault indicator beacon to draw attention of a repair person or other user.

There are at least three DIMM modules **450** depicted in FIG. 4, but embodiments of the present invention are not limited to a specific number of memory modules. Furthermore, although DIMMs **450** are depicted and discussed, embodiments of the present invention need not necessarily be limited to a specific type of memory module. Other types of memory modules include single in-line memory modules (SIMMs), Rambus in-line memory modules (RIMMs®), and others.

Each memory module **450** couples to the system board **400** by way of a memory slot. The memory slot is configured appropriately depending on the type of memory module. Again, while at least three memory slots are illustrated in FIG. 4, embodiments of the invention are not limited to a specific number of memory slots.

Each memory module **450** includes a plurality of DRAM chips **452** and a beacon unit **454**. The DRAMs **452** comprise volatile memory in that they require the application of power to retain data therein. Each memory module **450** also includes circuitry configured to provide read and write access by the memory controller **404** to the DRAMs **452**. Each memory module also includes circuitry configured to provide read and write access to a control register on the beacon unit **454**. In one embodiment, the read and write access to the control register is provided via a communications link to a memory error interface **406**. Alternatively, the read and write access to the control register may be provided via a communications link to the memory controller **404**, where the memory controller **404** is specially configured with capability to activate and deactivate the beacon state of the memory module **450**.

FIG. 5 is a flow chart of a method of locating a faulty memory module in accordance with an embodiment of the invention. This method is advantageous over the conventional method of FIG. 3.

Like in the conventional method of FIG. 3, sometime during the operation of the computer system, a memory error is detected **302**. The specific location of the memory error is determined **304**. The memory error detection **302** and location determination **304** may be performed, for example, by the operating system. The specific location may be indicated as being at specific address(es) of specific DRAM(s) on a particular memory module. To track the memory error, the memory error information is stored **306** in a system log. The system log may be kept, for example, on the system board or on a system disk.

In accordance with an embodiment of the invention, in addition to the memory error information being stored **306** in the system log, a beacon on the memory module is turned on **502** to draw the attention of a repair person or other person to the DIMM. The beacon device may be turned on by programming an associated control bit or flag in a register on that DIMM. The manageability processor may be configured to send communications to program the register on the DIMM for the beacon state. In addition, the operating system may be configured to access, through the manageability processor, the DIMM's beacon register to set the state. The beacon for a DIMM may be turned on, for example, by a system administrator or other user of the computer system to "flag" that DIMM, or by manageability or diagnostic applications.

With the beacon activated on the DIMM, a repair person or other person may readily visually locate **504** that DIMM from amongst the numerous DIMMs in a system. Once found, the DIMM may then be removed **310** for replacement or repair. The method of FIG. 5 is advantageous over prior techniques because it simplifies DIMM identification and lowers the need for diagrams and documentation.

In accordance with an embodiment of the invention, an example electromechanical beacon device is depicted in FIGS. 6A, 6B, and 6C. In this example, the electromechanical device comprises an electromechanical button or flag. Switches or other forms of electromechanical devices may also be used. FIG. 6A is a plan view (top view) of the example electromechanical device. FIG. 6B is a perspective view (side view) of the device with the electromechanical button or flag in the down (deactivated) position. FIG. 6C is a perspective view

(side view) of the device with the electromechanical button or flag in the up (activated) position.

Such electromechanical devices are particularly advantageous in that they do not require the application of power to the device in order to stay in an activated or "turned on" state. For example, during repair, often times power is removed from the system chassis. With such an electromechanical beacon device, the "flag" may be "popped" (like a circuit breaker) when activated. It will remain in the popped position, whether or not power is applied, until it is reset by a repair person or other user.

In the above description, numerous specific details are given to provide a thorough understanding of embodiments of the invention. However, the above description of illustrated embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise forms disclosed. One skilled in the relevant art will recognize that the invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring aspects of the invention. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

These modifications can be made to the invention in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of the invention is to be determined by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.